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Incident Pressure Measurement in Air Blast Using Wireless Sensors

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Abstract: This paper presents the wireless measurement of the incident pressure inside the fire ball of an air blast shock wave. The wireless sensor set-up and the experimental configuration are described. The wired and wireless experimental results are compared and analyszd. To our best knowledge, it is the first time that a wireless device takes place inside the fireball of an explosion for the measurement of the incident pressure in such harsh environment.

I. Introduction

Accurate measurement of the overpressure in an air blast experiment is very challenging. The pressure signal over time has very fast variations in time domain with a microsecond rise time. Each component of the measurement setup (transducer, conditioning unit, cables and recorder unit) requires a very large bandwidth in order to record the signal without significant distortion [1]. In addition, extreme conditions are also involved during the measurement. Temperature range is over 1000 degrees Celsius with intense light, reflected shock wave, vibrations, ionized gases which may impact the accuracy of the pressure measurement. The main goal of an air blast experiment is to compare the measured data with the numerical simulation results derived from the detonation products Equation of State (EOS). Recently, many efforts have been devoted for recording very fast transient pressure occurring during an air blast experiment [2]. Usually, pressure sensor networks use several long cables to connect the sensors to the acquisition unit. Transmitting fast pressure signal by using transmission cables causes typically a bandwidth reduction and the distortion of the measured signal (10 – 300 MHz at -3 dB depending on the cable type and length). Moreover, the destruction or degradation of the cables during the explosion experiment is a possible issue and may require time-consuming manpower. All these measurement issues have a significant impact on the reliability and the accuracy of the pressure measurement when using wired sensors networks [2, 3]. Managing a large number of wired sensors using long cables is not easy and may lead to several operational problems during the setup process [3]. As a matter of fact, during the maintenance operation, each cable should be checked after an air blast experiment in order to detect eventual electrical failure such as short-circuits or electrical breakdowns. To solve these problems, we propose here to use a wireless sensor instead of wired sensor to measure the pressure variation in an air blast experiment. A wireless RF link is used for the first time to read the data from pressure sensors under harsh environment in terms of temperature, pressure and mechanical vibrations. Moreover, the cost and size of the RF system are minimized in order to perform a very attractive solution for the air blast measurement experiment. In the following sections, we will present for the first time a wireless measurement that takes place inside the fireball of an explosion to record successfully the transient pressure signal.

II. RF Wireless Sensors Setup

The wireless setup reported here is composed of transmitter and receiver units operating at 6.0 GHz with 100 MHz bandwidth (see Fig. 1). During the experiment the transmitter unit converts with the voltage controlled oscillator (VCO) the output voltage of the piezoelectric sensor (based on a PVDF film) into a frequency shift. The resulting frequency modulated (FM) signal is transmitted to the receiver unit through the fireball. The received FM signal is filtered and amplified by the receiver unit. The intermediate frequency (IF) is obtained by mixing the received modulated signal with the stable sinusoidal signal generated by a 6 GHz Local Oscillator (OL).

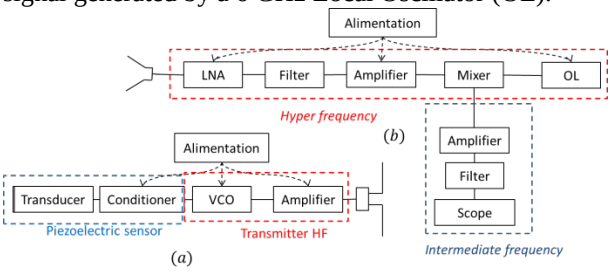

Fig. 1. Block diagram of the wireless sensor setup: (a) transmitter unit; (b) receiver unit.

The frequency demodulation process applied to the IF signal is performed numerically by using the classical

Short-Time Fourier Transform (STFT). The -3 dB bandwidth of the wireless system is 100 MHz. It is large enough to ensure the transmission without noticeable distortion of the signal bandwidth mainly limited by the dynamic response of the sensor transduction.

III. Experimental Setup and Measurement Results

The wireless experimental set-up is illustrated in the Figure 2. The transmitter unit (including the piezoelectric sensor) is placed inside the fireball during the blast event for sensing the pressure signal variation very close to the explosive. The transfer function of the conditioner has been characterized. The sensing device is located at 1.6 meter of 1 kg TNT sphere, the HF transmitter is positioned at 1.3 meter. Both the wireless link and a RG58 coaxial cable link are used between the transmitter and receiver units to remotely and simultaneously read the pressure variations measured by the sensors. These two links allow to compare the measurement results obtained from the wired and wireless systems. The receiver unit is located at 22 meters of the explosive in front of a bunker. An ultra-fast camera is also installed to capture the fireball expansion. In Figure 3a the fireball interface is indicated by the red circle while the shock wave interface is noticed with the blue circle. The pressure signal is transmitted in real time when the shock wave reaches the pressure sensing device. During the measurement process the internal temperature of the sensor is found to be lower than the highest admissible temperature of the sensor, verified by acoustic-electric computations inside the gauge, air blast predictions and air temperature measurements..

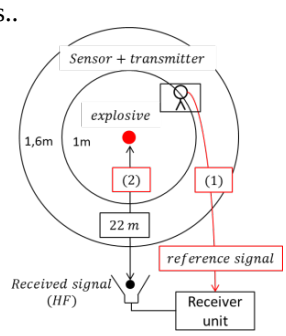

Fig. 2. Experimental wired (1) and wireless (2) set-up.

The wireless measurement is derived from the demodulation of the received signal. The difference between wireless and wired measurement data does not exceed 100 mbar (4.3 %). The transient part of the signal is successfully transmitted by the proposed wireless system and by the cable. During the transient phase the static overpressure peak is measured at 2.3 bar with a rise time around 1 µs. The positive phase (Figure 3b) duration is around 100 µs. A discrepancy on the impulse has been observed with the quartz sensor due to the applied conditioner with a too high low pass frequency.

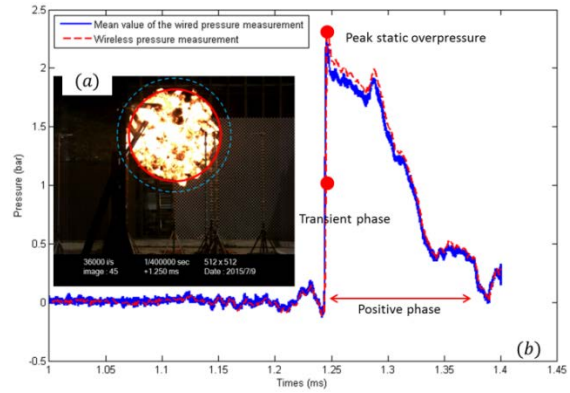

Fig. 3. (a) Fireball during the air blast event (1.2 ms after the explosion); (b) Demodulated signal

IV. Conclusion and Perspectives

A wireless sensors solution is proposed for measuring the pressure variation in an air blast event. Based on a single VCO component, the transmitter is able to send wirelessly high bandwidth (<100 MHz) pressure sensor signal in harsh environment with a specified impedance matching. FM demodulation and numerical post-processing treatments performed on the received signal allow measuring the pressure variation in the fireball during the blast. Wireless sensor network for air blast measurement is a promising alternative to wired network classically used in this type of experiment in terms of reliability, measurement accuracy and cost.. The comparison with the quartz sensor will be further investigated and compared with detonation products EOS numerical simulations. Moreover, wireless sensor devices have also several potential error sources, such as the dynamic displacement of the transmitter antenna during the explosion, the temperature dependence of the voltage controlled oscillator (VCO) and the autonomous battery integration. The impact of these issues on the measurement accuracy and reliability have to be minimized during the development phase.

References

[1] Silver, P. L., “Evaluation of Air Blast Measurement Techniques”, *75th Shock and Vibration Proceedings*, Virginia Beach, VA, October 17 - 22, 2004.

[2] Walter, Patrick L., “Air-blast and the Science of Dynamic Pressure Measurements,” *Sound and Vibration*, pp. 10-16, December 2004.

[3] Subramanian, C.S.; Pinelli, J.-P.; Lapilli, C.D.; Buist, L., "A wireless multipoint pressure sensing system: design and operation,"*IEEE Sensors Journal*, vol.5, no.5, pp.1066-1074, October 2005.